Modeling the impacts of climate change on fisheries and marine ecosystems
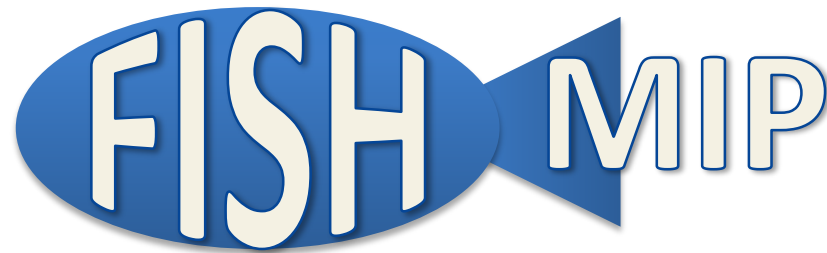
Heike Lotze, Tyler Eddy, Eric Galbraith, William Cheung, Derek Tittensor

BLUE PLANET

- **Future of fish & fisheries?**

- **Seafood supply?**

- **Marine biodiversity?**

- **Ecosystem functioning?**

=> Observed vs modelled effects

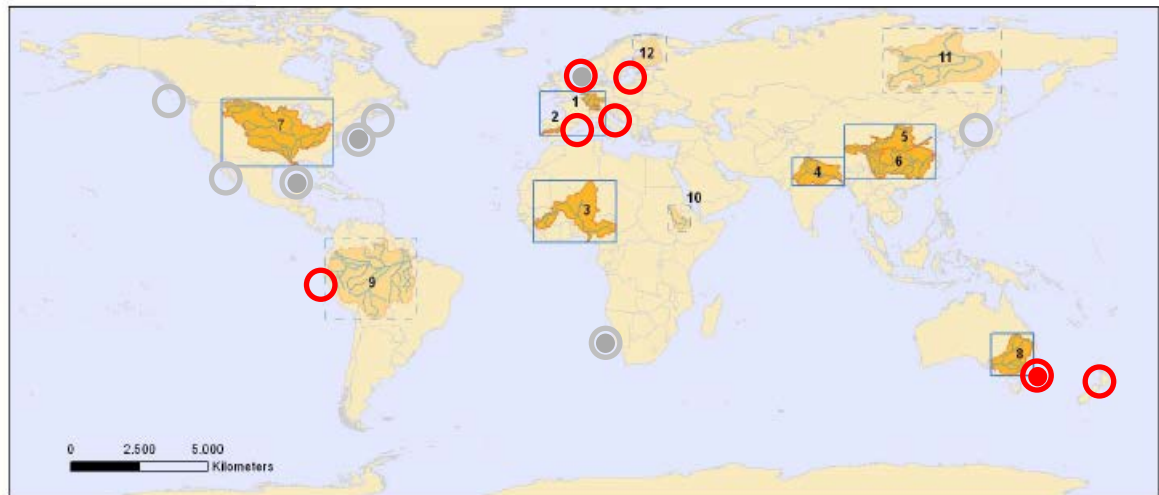# Marine ecosystem models

GLOBAL

1. BOATS
2. Macroecological
3. DBEM
4. SS-DBEM
5. DBPM
6. APECOSM
7. POEM
8. EcoOcean
9. Madingley
10. SEAPODYM

REGIONAL   (#regions)

1. EwE   (6 + 6)
2. Atlantis   (1 + 2)
3. OSMOSE   (1 + 3)
4. Size-structured (2)
5. End-to-End (1)

Goal

$\Rightarrow$ use same future climate scenarios as other ISI-MIP sectors

- 5 GCMs, 4 RCPs
- adapt to oceanic climate change scenarios

$\Rightarrow$ use same shared socioeconomic pathways (SSPs)

- human population growth and GDP
- adapt to future fishing scenarios

Challenges

- very varied marine ecosystem model structure, regional vs global
- very new, not yet completely refined
- very different purpose, design, input & output data
- GCMs limited 3D depth- & monthly-resolved physical & biogeochemical data
- coastal areas not well represented
- limited observational data for historical runs and model validation
- limited data on spatially resolved fishing effort and future scenarios

GCM selection

- GCM 1 = HadGEM2-ES   (unreliable plankton data)

- **GCM 2 = IPSL-CM5ALR** ✓

- GCM 3 = MIROC-ESM-CHEM   (no size-resolved plankton groups)

- **GCM 4 = GFDL-ESM2M** ✓

- GCM 5 = NorESM1-M   (no size-resolved plankton groups)

- [**CESM1-BGC**   (RCPs 4.5 & 8.5 only)] ?

- RCPs 2.6, 4.5, 6.0, 8.5

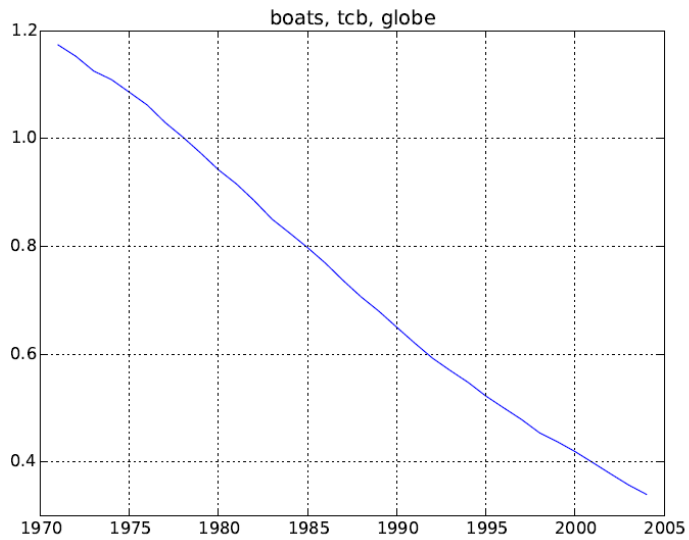- Ocean Acidification   yes-no

- Fishing yes-no

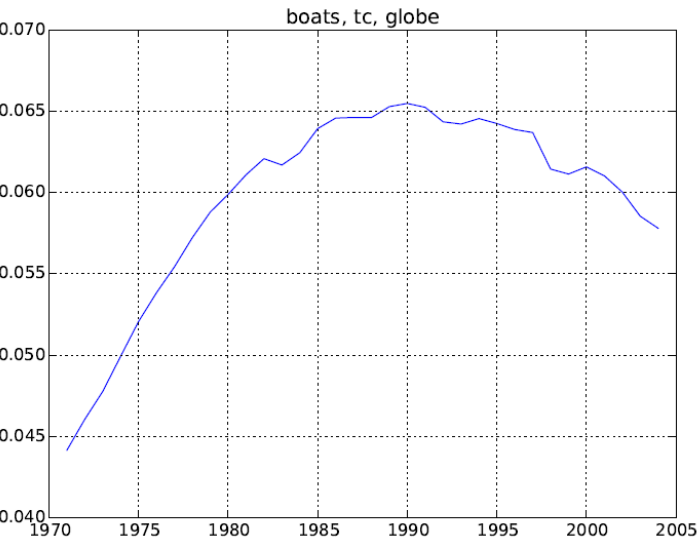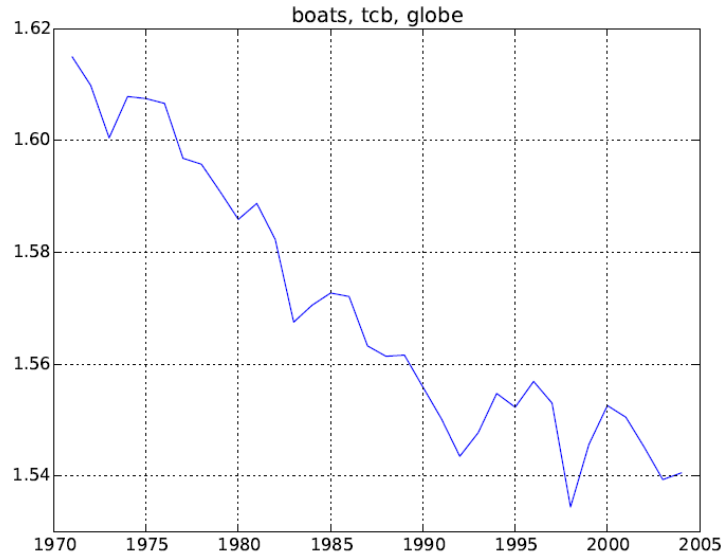Bopp et al. 2013, *Biogeosciences*
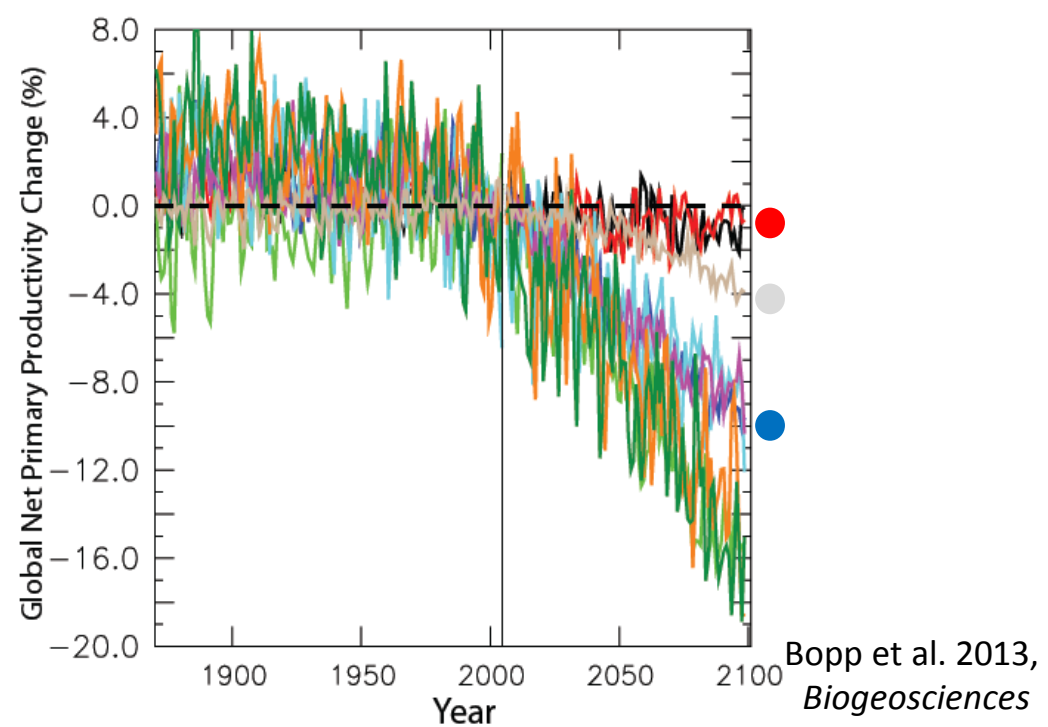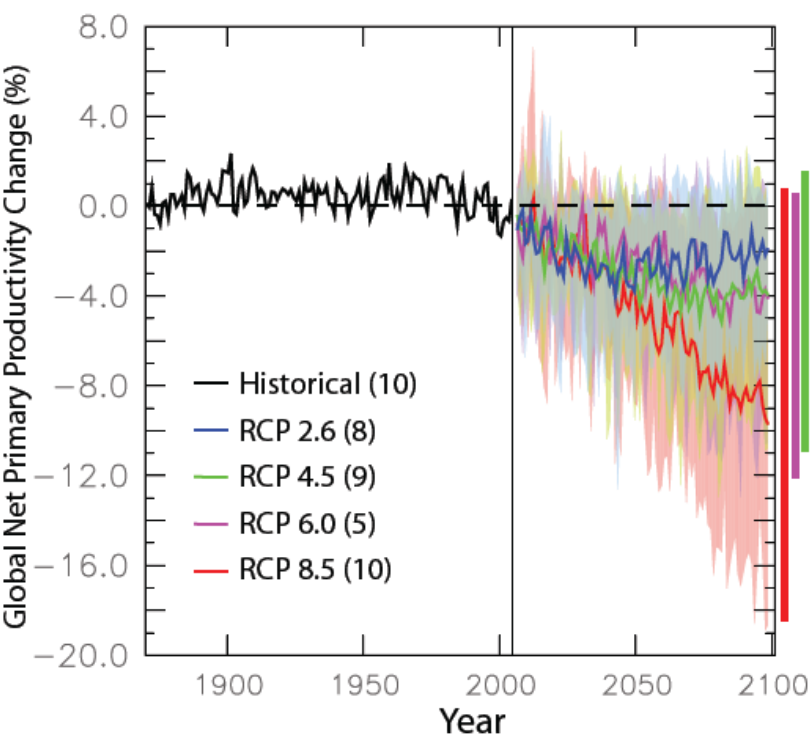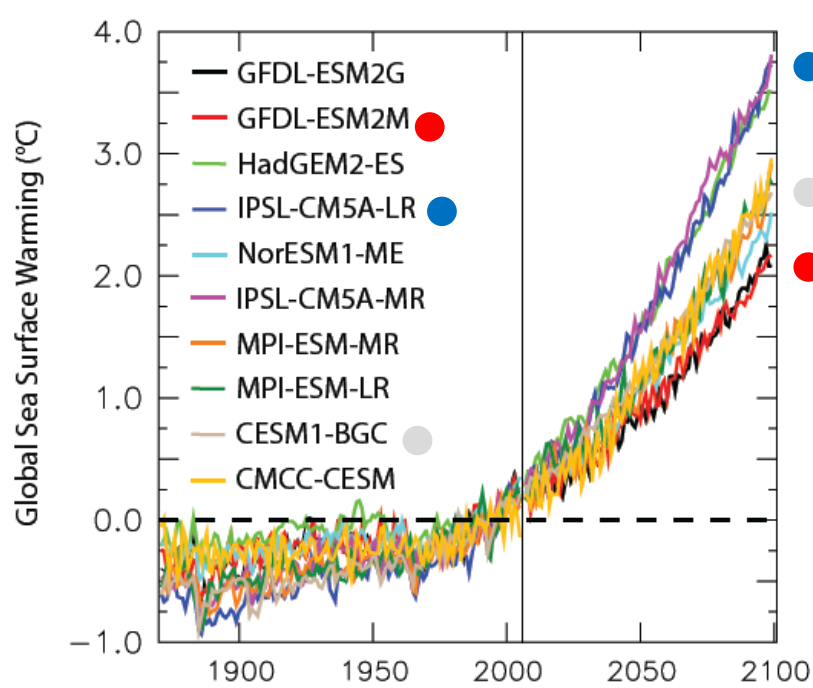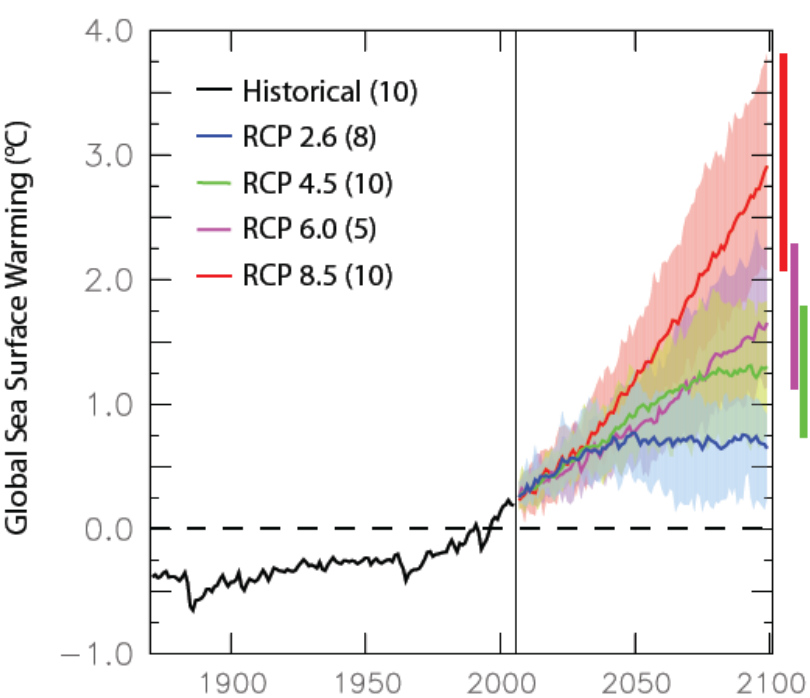
First results

- Total system biomass (tsb)
- Total consumer biomass (tcb)
  - with/without fishing
- Total catch (tc)
- Biomass of small and large consumers
  - with/without fishing
  - changes moving through the food web
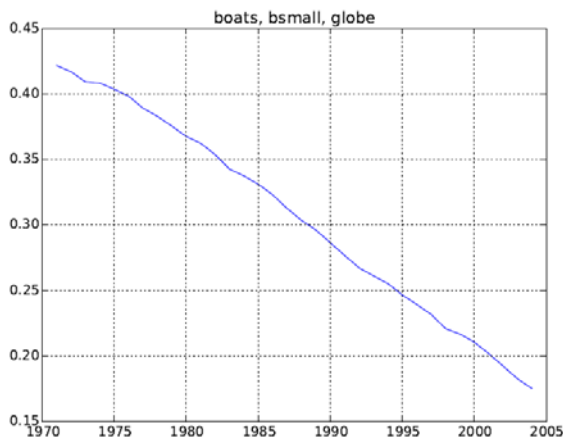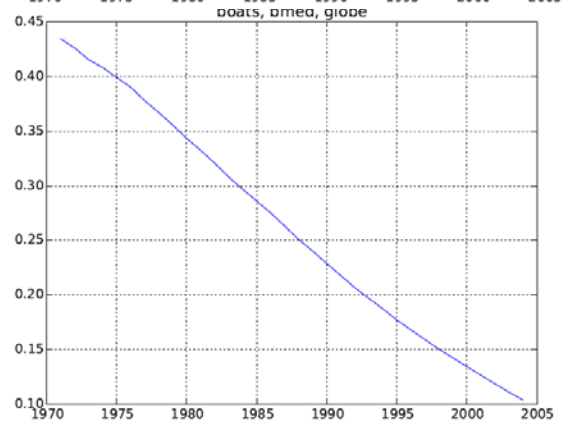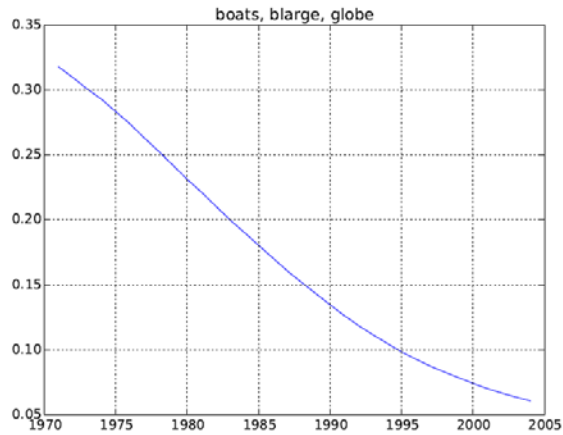
Historical validation

Fishing

boats, tcb, globe

No Fishing

boats, tcb, globe
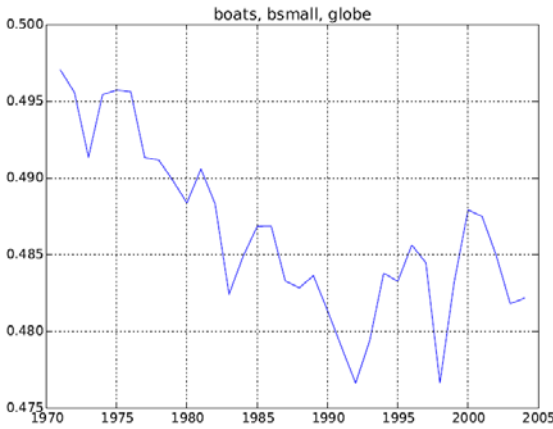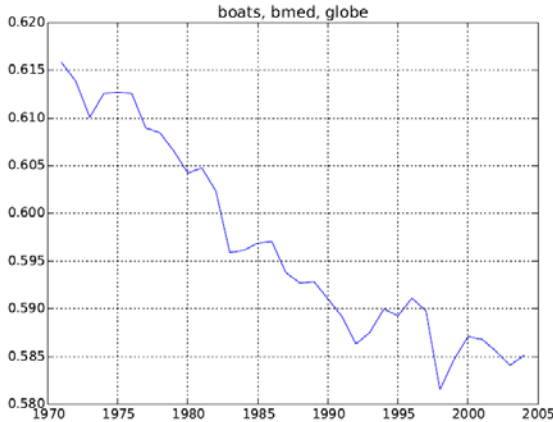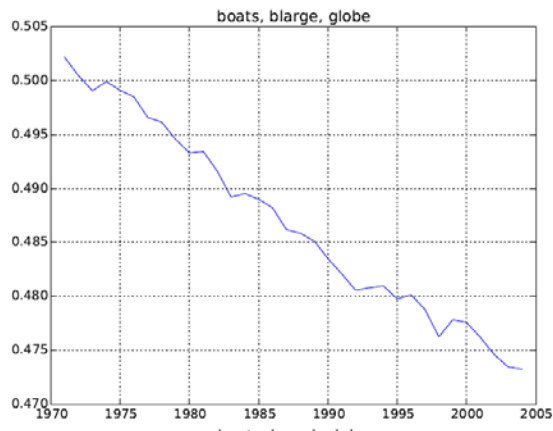

boats, tc, globe

BOATS, GFDL-reanalysis

- Fishing stronger than climate effect
- Tracking extreme events

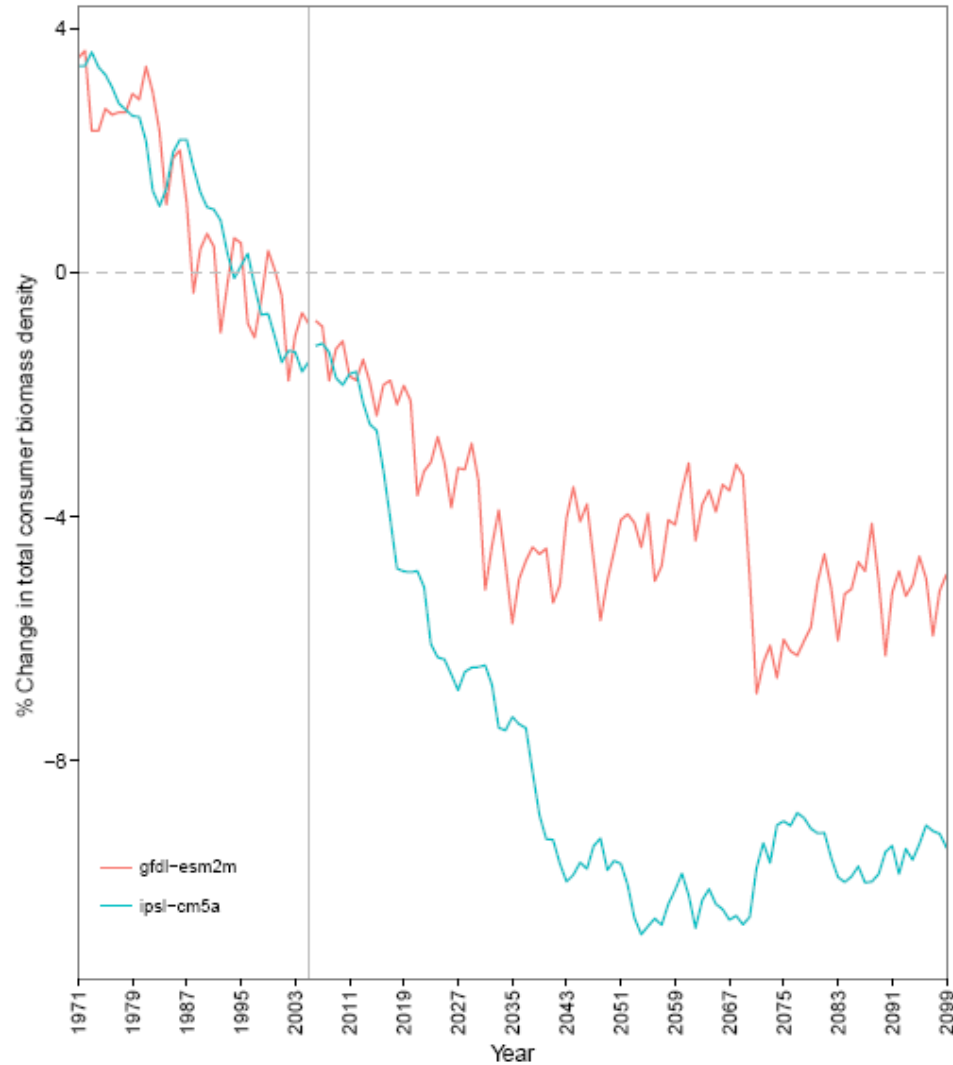**Fishing**　　　　　**No Fishing**　　　　　# BOATS
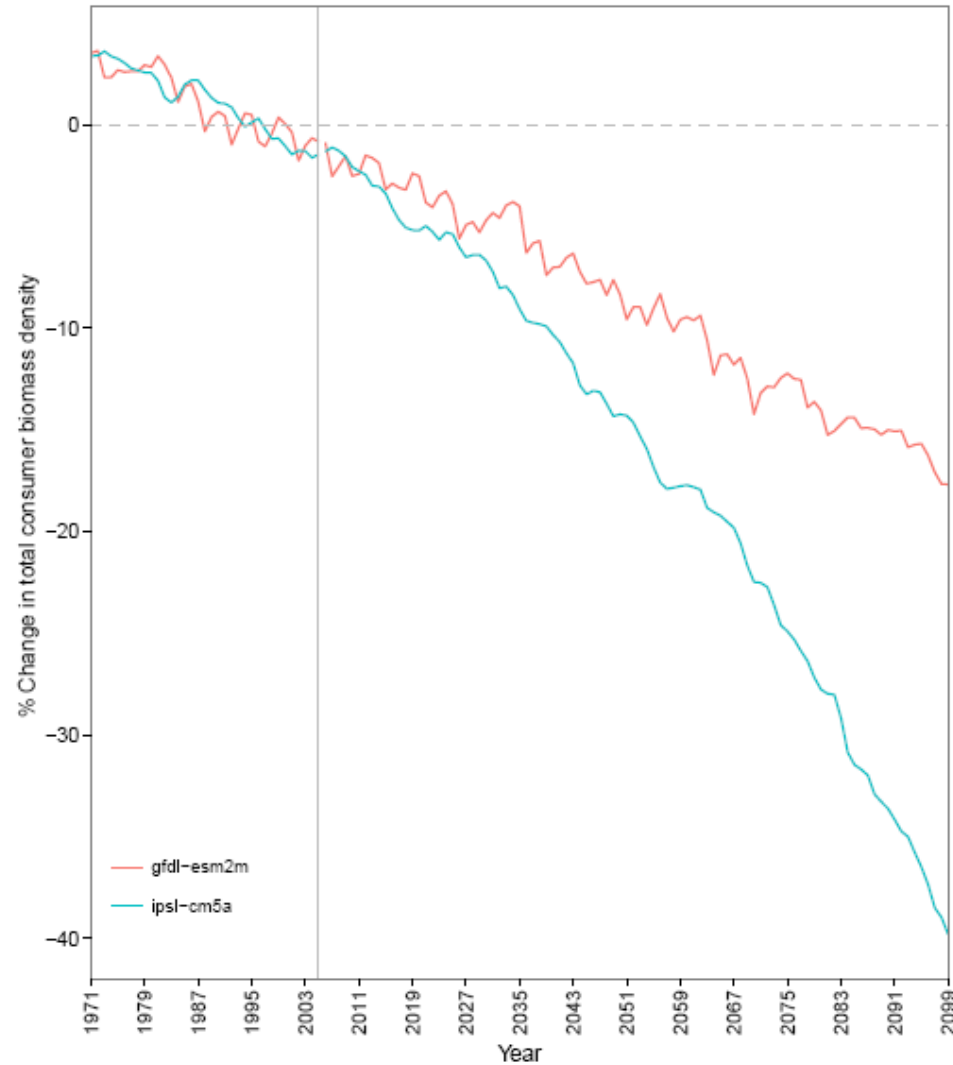GFDL-reanalysis
size groups

large

medium

small

Future projection
BOATS, abundance – no fishing

APECOSM
abundance – no fishing [IPSL]
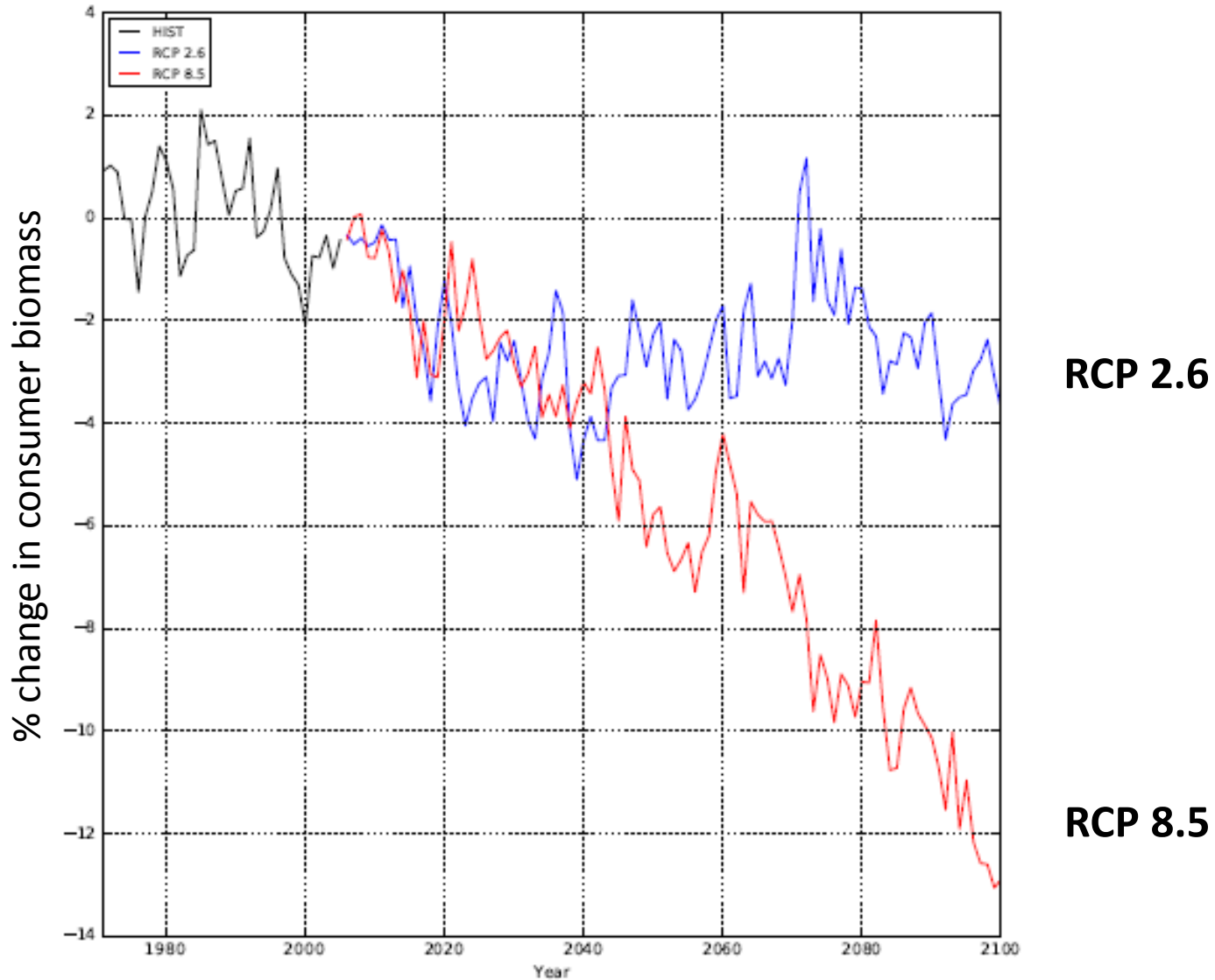
Overview

	RCP 2.6		RCP 8.5		
	GFLD ESM2M	**IPSL CM5A LR**	**GFLD ESM2M**	**IPSL CM5A LR**	
	0.5°C	1.5°C	2.0°C	4.0°C	*SST 2100*
	1.3° C	*1.8° C*	*3.0° C*	*4.7° C*	*GMT 2100*
BOATS	-5%	-10%	-15%	-40%	*tcb no fishing*
MACRO	-3%	-10%	-12%	-32%	*tcb no fishing*
APECOSM	---	-3%	---	-13%	*tcb no fishing*
DBPM					*tcb no fishing*
BOATS	-55%	-25%	-60%	-40%	*tcb fishing*
DBEM	-3%	-8%	-8%	-34%	*tcb fishing*
SS-DBEM	5%	---	8%	---	*tcb fishing*
BOATS	-28%	-23%	-33%	-58%	*catch*
DBEM	-5%	-3%	-10%	-22%	*catch*
SS-DBEM	?		?		*catch*

Regional changes
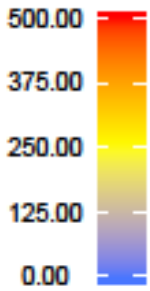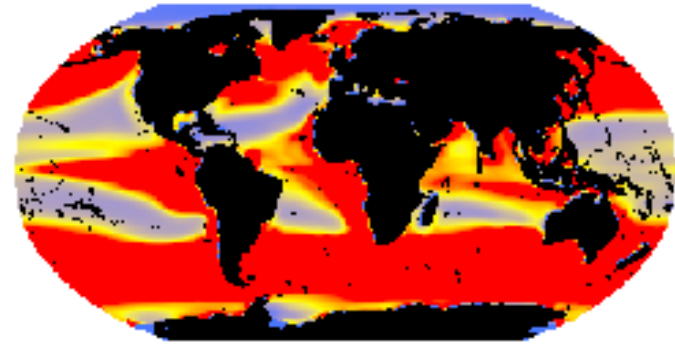

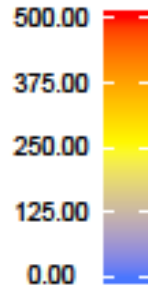
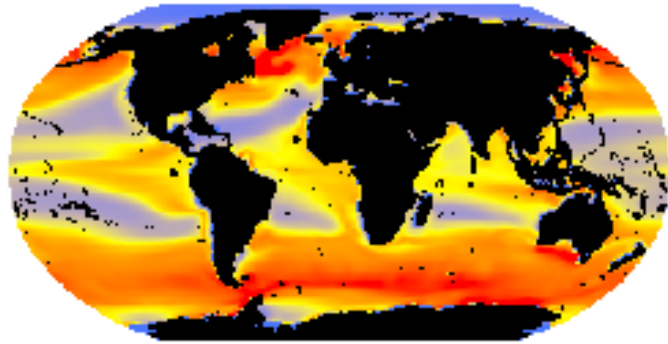tcb, annual mean
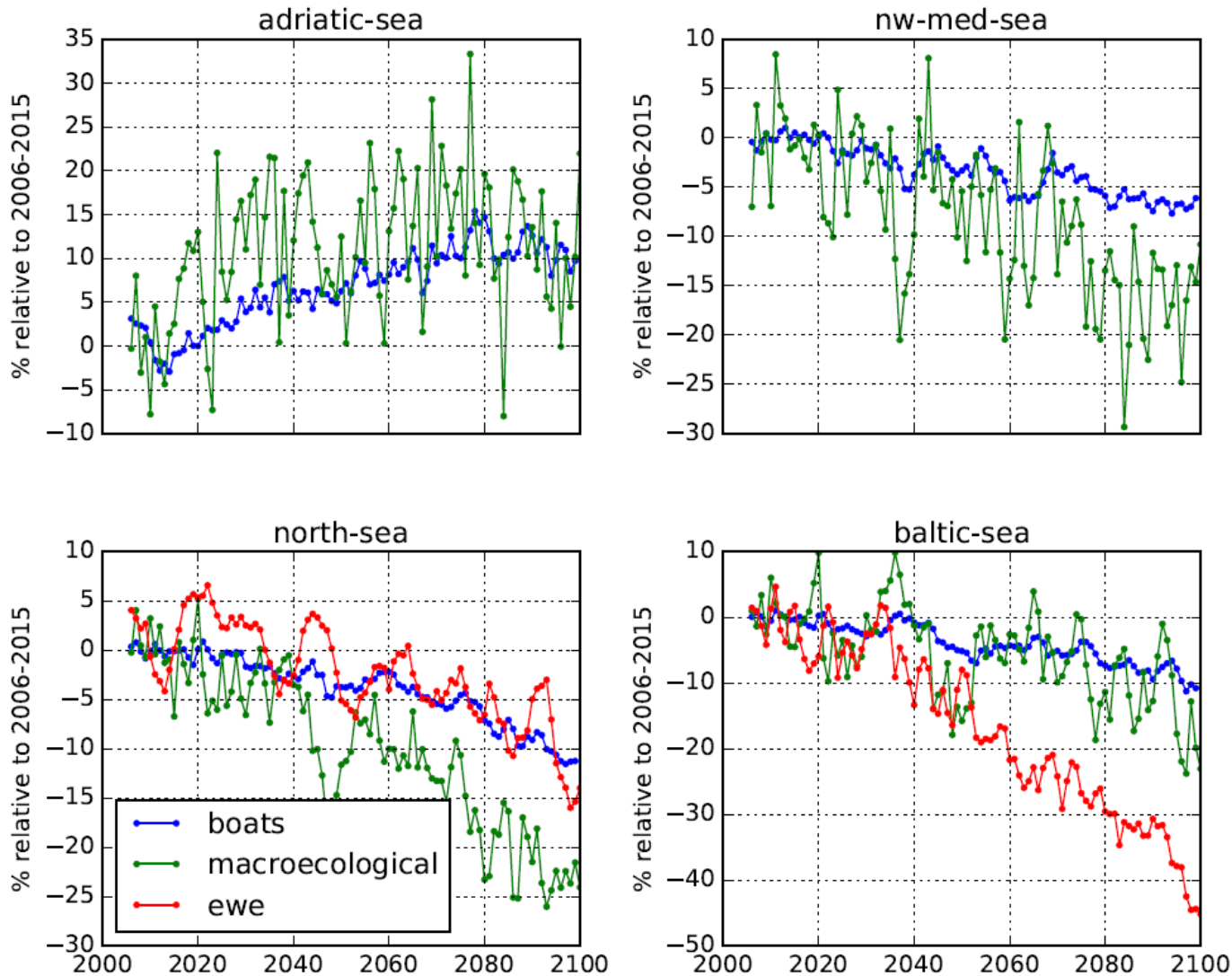
GFDL-ESM2M, RCP8.5
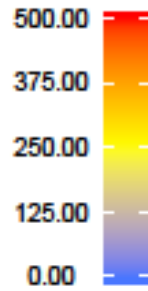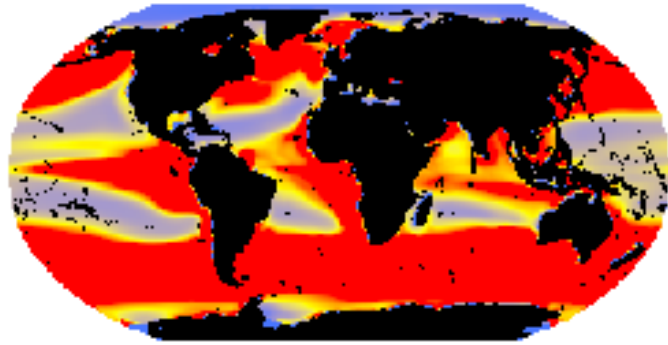
BOATS

IPSL RCP 2.6

ipsl–cm5a–lr fishing 1971–1979 mean tcb kg km–2

ipsl–cm5a–lr fishing 1990–1999 mean tcb kg km–2

ipsl–cm5a–lr fishing 2090–2099 mean tcb kg km–2

IPSL RCP 8.5

ipsl–cm5a–lr fishing 1971–1979 mean tcb kg km–2

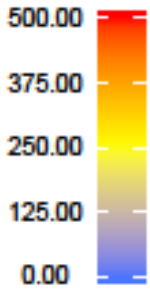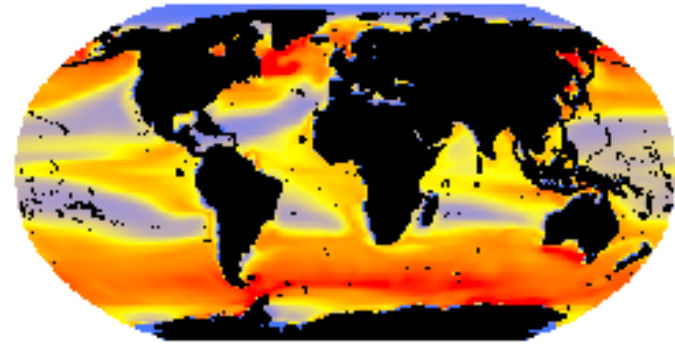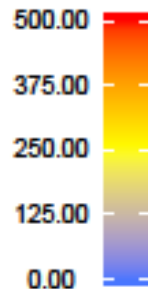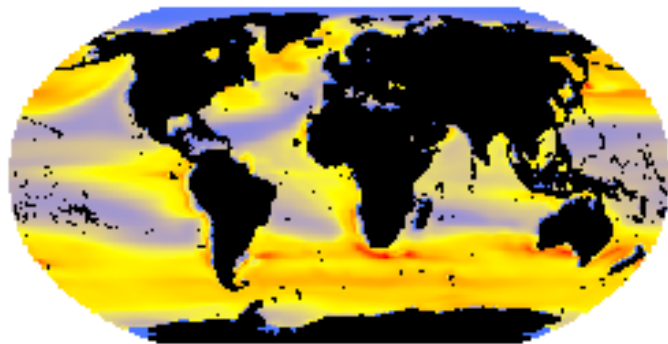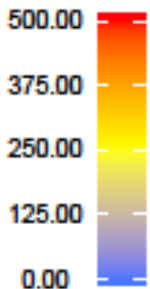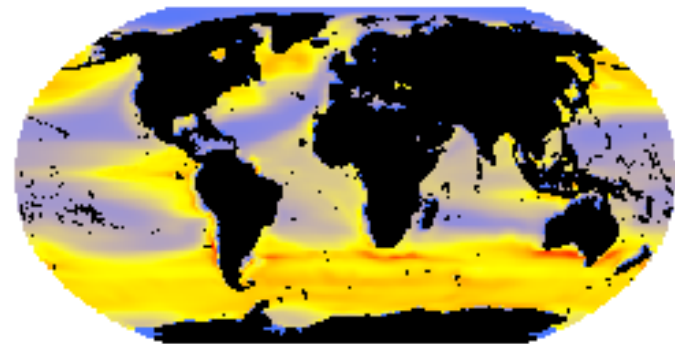ipsl–cm5a–lr fishing 1990–1999 mean tcb kg km–2

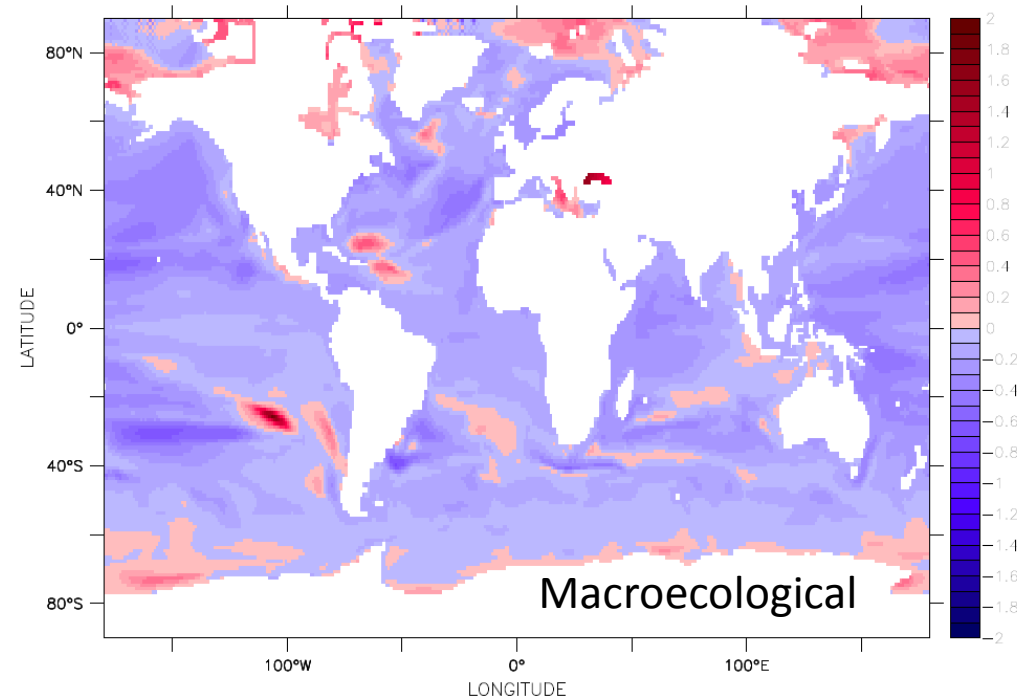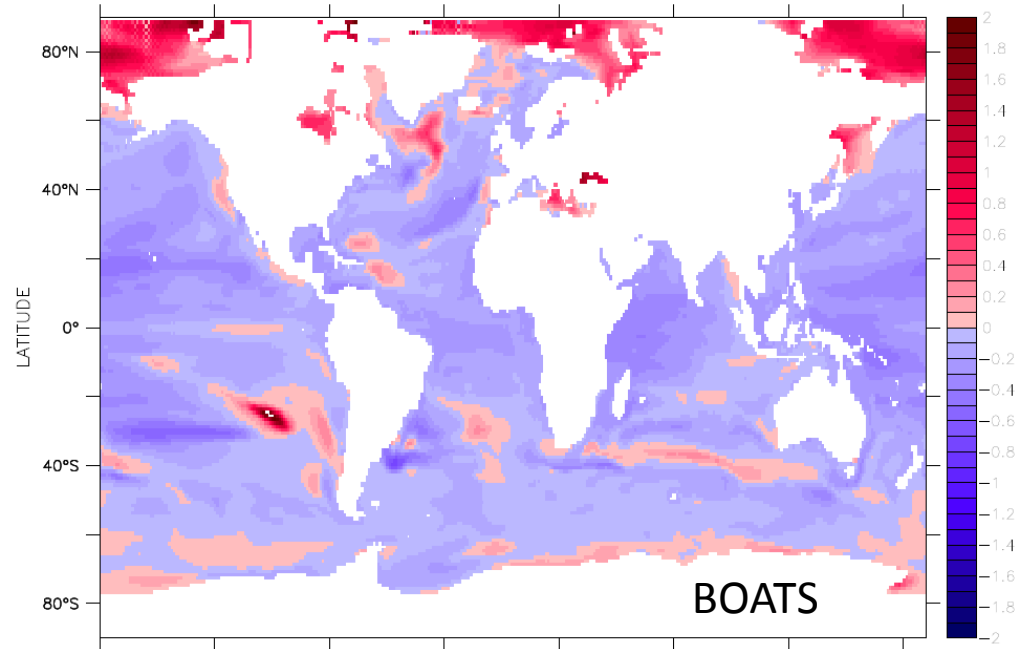ipsl–cm5a–lr fishing 2090–2099 mean tcb kg km–2

Relative change

Total consumer biomass,
2070-2099 vs 2006-2035
GFDL-ESM2M, RCP8.5

Publications

- **FISH-MIP**
  - Methods paper (Tittensor et al., submit soon)
  - Case study New Zealand (Eddy et al., submit soon)
  - Historical runs & validation (Eddy et al. in prep)
  - Future runs (Lotze/Tittensor et al. in prep)
  - Uncertainty analysis (Cheung et al. in prep)
  - 2003 heat wave paper (Schewe et al. in prep)
  - Extreme events (e.g. El Ninos)
  - …

Future plans

Simulations:
- Pre-industrial control runs
- Extended RCP 2.6 scenario to 2300
- Historical 1860-1950 fishing scenarios (hindcasting)
- Future fishing scenarios (based on SSPs)
- Ocean acidification (yes-no)

Cross-sectorial plans:
- Global food production & protein supply (*Agro-Economics sector*)
- Biodiversity changes on land & in the sea (*Biodiversity sector*)
- Land-use changes and nutrient run-off (*Agriculture/Water sectors*)

Management:
- New Lead Coordinator: Derek Tittensor